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14. ABSTRACT
Burn patient outcomes are dependent on the wound surface area as a percent of the total body surface area (%TBSA), burn locations, burn depth, and patient age. %TBSA is essential in determining fluid resuscitation and nutrition support, and surgical intervention and rehabilitation planning. The proposed burn injury assessment software tool is aimed at increasing %TBSA accuracy by improving on both TBSA and burn area estimations. Conventional methods (Rule-of-Palm/Nines and Lund-Browder chart) use a generic 2D body shape diagram to represent the human body which lacks the capability to capture 3D anthropometric variability of actual human body shapes, resulting in inaccurate %TBSA. This burn assessment tool will include an interactive anthropometry-based human body generator to create, in real-time, a personalized 3D body shape model that has been morphed according to available subset of adjustable anthropometric measurements (weight, age, gender, height, waist, arms and legs measurements) as stored in most anthropometry databases. To improve on burn area estimations, the burn tool will allow the user to interactively demarcate burn areas of varying severity directly on the personalized 3D model for calculation of %TBSA. Photographic image assisted burn demarcation and Android version of the prototype were developed.

15. SUBJECT TERMS
Burns, Burn size, Burn assessment, Over-resuscitation, 3D anthropometry modeling, Anthropometric morphing, Cutaneous functional units, Image assisted burn assessment, Computer aided burn assessment.

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1. INTRODUCTION

1.1. Project Scope

The overall objective of this project is to develop a burn injury assessment tool with morphable 3D anthropometric human body models in order to improve the accuracy of percentage burn surface area estimates. Phase I Base period produced a functional prototype that can create anthropometrically morphable body models in real-time for interactive demarcation of burn areas based on burn severity and compute %TBSA. Phase I Option focuses on further developing the capabilities and expanding the platform to mobile devices. The main tasks of this Phase I Option project are:

1. Develop the use of photographic images of burned body parts to assist in burn demarcations.
2. Burn injury assessment prototype on Android tablet device will be created.

This DoD Army SBIR Phase I Option project started on 12/22/2016 and is scheduled for completion on 04/21/2017. This project is conducted by the Computational Medicine and Biology (CMB) Division of CFD Research Corporation (CFDRC) in Huntsville, AL. in collaboration with Professor David N. Herndon of the University of Texas Medical Branch at Galveston (UTMB) who serves in this project as the Scientific Consultant.

1.2. Project Purpose and Significance

Burn patient outcomes are dependent on the surface area of the wound as a percentage of the total body surface area (%TBSA), burn location(s) on the body, depth of the burn(s), and age of the patient. %TBSA is essential in determining burn casualty treatment [1] and rehabilitation [2]. Conventional methods (Rule-of-Palm/Nines and Lund-Browder chart) may result in inaccurate %TBSA since they use a generic 2D body shape diagram to represent the human body. This fixed 2D template lacks the capability to capture 3D anthropometric variability of actual human body shapes. The objective of this project is to develop a burn injury assessment software tool that can create anthropometrically realistic 3D virtual human body models in real-time using anthropometry data as inputs. This 3D human body model will be used to demarcate burn areas based on burn severity and compute the %TBSA. Figure 1 shows the prototype developed with burn demarcation and calculation on a morphed 3D human body model.

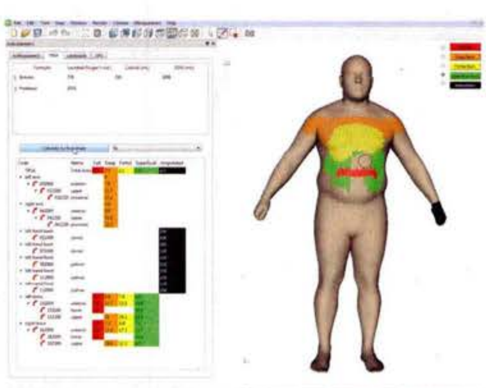


Figure 1: Prototype showing demarcation of burn areas on a morphed 3D model.

2. OVERALL PROJECT SUMMARY

The following sections describe work performed and results obtained for each task in the project.

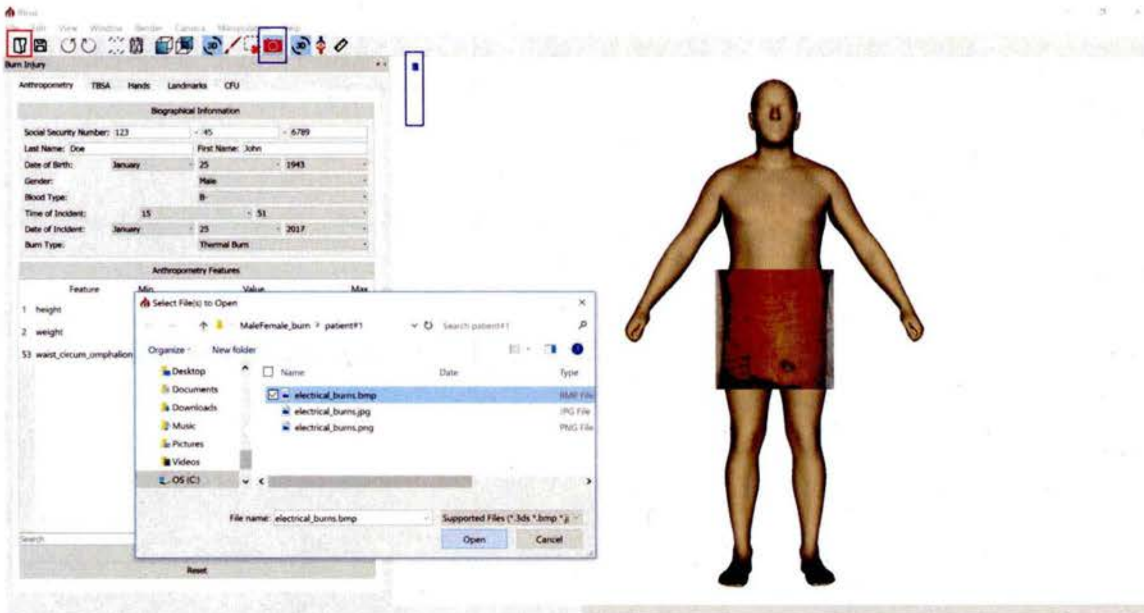
2.1. Option Task 1: Image Assisted Burn Injury Assessment

There is physician subjectivity involved in transcribing burn severities and locations from a patient onto a virtual representation [3] as well as greater inaccuracies with small scattered burns compared to a single area burns. Typically, patients with small scattered burns are scored higher %TBSA overestimation compared to patients with a single large burn area [4]. Physicians also generally tend to overestimate burn areas rather than underestimate them [5]. Even the most experienced burn physicians routinely overestimated %TBSA by 20%, while the less experienced ones overestimated by up to 49% [1].

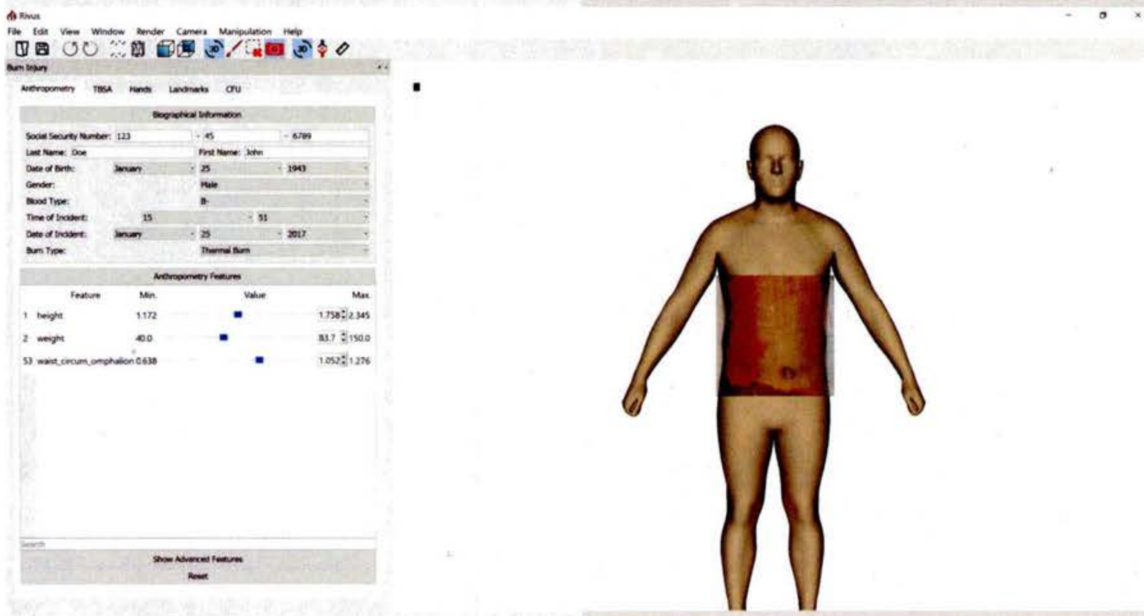
To eliminate physician subjectivity and obtain accurate, repeatable burn area demarcations, photographic images of the wounds, often taken to the burn severity and location, are loaded into the graphical user interface (GUI) and superpositioned onto the 3D human body model by manual orientation and scaling. Upon loading an image, the image button, initially grayed out, is toggled on and a slider automatically appears to allow the user to adjust the opacity of the photo for better visualization (Figure 2a and b). The 3D model is interactively manipulated to align and match the image with the model. An automatic landmark-based alignment using at least 3 corresponding points picked by the user on the 2D photo and the 3D model may be applied. However, the large variations in postures, scales, angles, and errors in user selection of corresponding landmarks in both the photo and model may make this process highly error-prone, requiring multiple attempts and further user intervention to make alignment corrections. To eliminate repeated landmark selection by the user and possible frustration with the automated alignment process, we decided to simply have the user manipulate the 3D model to manually align with the photograph. In Phase II, we plan to develop a photo acquisition guide in the mobile version of the tool to direct the user to take images of the patient using the built-in camera of tablets at the correct zoom and angle for direct alignment with the 3D model without any post-processing registration.

Ideally, the patient's anthropometry measurements should be entered first to obtain a personalized 3D model for image alignment. However, for this example, since the burn image was downloaded from the internet [6], these body shape details are unavailable. Therefore, only the chest, hip and waist circumferences were adjusted to get a better match the body with burn image (Figure 2b). Once aligned, the burn areas are then traced onto the model objectively, using the photo as a guide for a truer and quicker one-to-one transcription (Figure 2c). The image can be shown or hidden by toggling on or off the image button. In Figure 2d, the burn surfaces areas and Brooke and Parkland fluid recommendations are calculated. Additionally, the buttons and icons to the GUI have been modified and updated. For greater usability of this capability in the software tool, support for more image formats was added to include BMP, JPEG, PNG and TIFF.

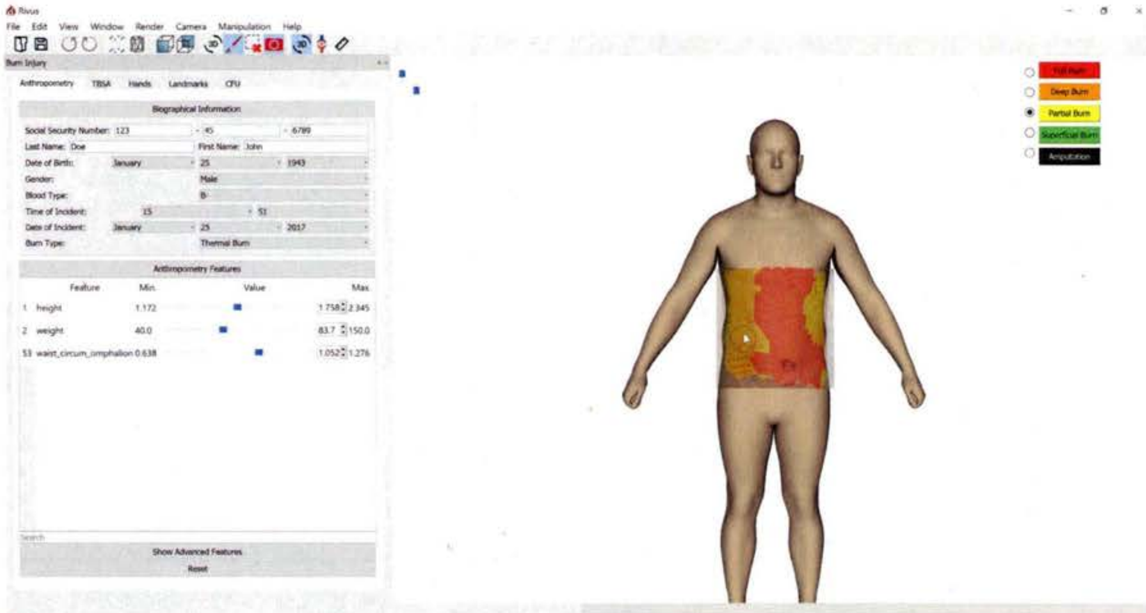
(a)



(b)



(c)



(d)

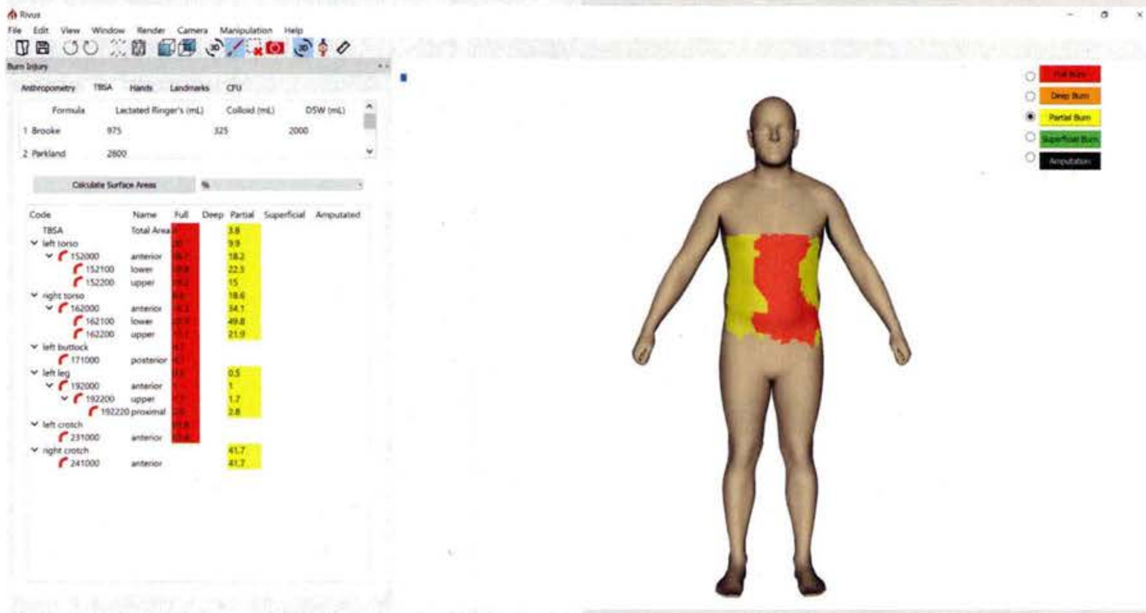


Figure 2. Screenshots of the image assisted demarcation. (a) The initial superpositioning of the loaded image (boxed in red) on top of the 3D model and the automatic appearance of the transparency control slider (boxed in blue). (b) Adjustment of the transparency slider changes the opacity of the loaded image for better visualization during manual alignment and tracing. (c) Tracing of the burn areas with different severity based on the image onto the 3D model. (d) Calculated burn surface areas in cm^2 and fluid recommendations with image overlay turned off. The burn image shown was download from [6].

2.2. <u>Option Task 2: Mobile Burn Injury Assessment Prototype</u>

The latest Android tablets currently available for purchase have Android 6.0 (Marshmallow, Android Programming Interface (API) level 23) installed. As such, we have developed our burn

injury assessment application targeted for API 23. The open-source, cross-platform integrated development environment (IDE), Qt Creator, was installed with open-source graphical user interface toolkit, Qt 5.8, for armeabi-v7a processor and linked to Java Development Kit 8 as well as Android NDK (Native Development Kit) r13b and Android SDK (Software Development Kit) v2.2.3. The Android application package (APK) of our burn software was created for the application binary interface (ABI) with ameabi-v7a and API 23. To facilitate this, a Project (.pro) file was written to use with Qt's qmake, replacing the need for CMake to create Makefiles. CMake is now no longer a requirement and development is carried out entirely on Qt Creator. In addition to Qt, the open-source 3D graphical visualization toolkit, Openscenegraph (OSG), is needed for 3D display and it is supported on Android and iOS. Static OSG libraries for API 23 and armeabi-v7a, with Qt support for Android and OpenGL ES 2.0 compatible graphics processing unit, were compiled and were linked to our code in Qt Creator in the .pri configuration file.

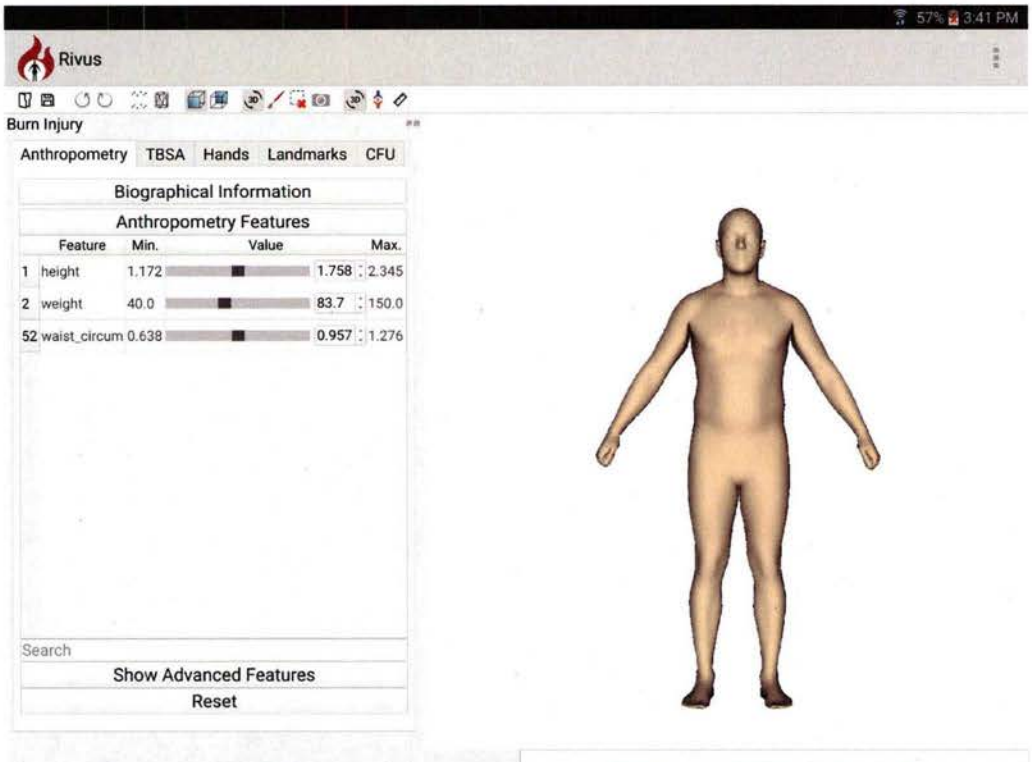
Some parts of the existing code that is supported with Standard C++ Library for C++11 (`std::stoi`, `std::stof`, `std::round` and `auto`) were refactored since these C++11 functions are not yet supported with Android NDK r13b. Alternatively, full Standard C++11 Library is supported with a 3rd party NDK, CrystaX NDK 10.3.2 [7], which does work with our existing code without modification. However, current CrystaX NDK is only supported for certain APIs and up to level 21. As such, we will continue development with Android NDK, taking note of which parts of the algorithm can be replaced by C++11 functions which is reported to be available in future releases of Android NDK. At current count, there are only 4 of such functions in our code.

Further modification of the code was carried out to ensure cross-compatibility with Android and Windows operating system. The input files needed for real-time human body morphing, which includes the mean human body model, eigenvectors and eigenvalues from the principle component analysis (PCA), and cutaneous functional unit (CFU), landmarks and anthropometric feature definition files for male and female, are set up to be bundled into the executable (APK, Windows EXE) during compilation. Qt has a platform-independent resource system that allows files to be stored in the executable. Since only the executable will be distributed, this provides some added measure of security to protect the PCA data from the ANSURII survey [8] that was kindly provided to us from the Warfighter Directorate at U.S. Army Natick Soldier Systems Center (NSRDEC) through another SBIR Phase II project with CFDRC and the U.S. Army, "Whole-body Anthropometric Design Models for Protective Equipment Design". Each bundled input file is accessed through the creation of a temporary file within Qt that immediately after reading, automatically gets deleted. For the mean male and female human body model PLY (Stanford File Format) files, however, further modifications had to be made. These files were previously read using the OSG library which depends on the file extension type to determine which CAD (computer aided design) plugin to use. For example, files with OBJ extensions are read with Wavefront OBJ reader plugin, and PLY files are read with Stanford File Format reader plugin. However, the creation of the Qt temporary files eliminates this extension information, while still preserving the contents of the CAD files, but nevertheless the OSG library is unable to read it. Furthermore, the OSG library's PLY reader plugin is not available on Android, only on Windows and Linux, due to the lack of support with `std::exceptions` with the Android

NDK. To circumvent both these issues, a custom PLY reader was implemented to bypass the OSG library and protect the 3D mean human body model CAD files.

The APK targeted for API 23 and armeabi-v7a processor can be created and runs on an Android device (Figure 3 and Figure 4). All the input files are processed and successfully parsed into the Anthropometry, TBSA, Landmarks and CFU tabs on the left side of the GUI. On the right side of the GUI, the male and female human body models are visualized and can be rotated and scale with 2-finger pinching on the touchscreen. For compatibility with the OpenGL ES v2.0 graphics driver on modern graphics cards, the Qt class, QGLWidget now obsolete, used for rendering OpenGL graphics integrated into Qt was upgraded to QOpenGLWidget class. These modern graphics cards use programmable shaders that compute the levels of light, shadows and color in the 3D scene. The most commonly used shaders are vertex and fragment shaders. Vertex shader defines the attributes of the vertices while fragment shader defines how the pixels between the vertices appear. As such, individual vertex and fragment shaders were written for the 3D human body model (Figure 3a and Figure 4a), spherical landmarks (Figure 3c and Figure 4c) and CFUs (Figure 3d and Figure 4d).

(a)


57% 3:41 PM
Rivus
Burn Injury
Anthropometry TBSA Hands Landmarks CFU
Biographical Information
Anthropometry Features
Feature Min. Value Max.
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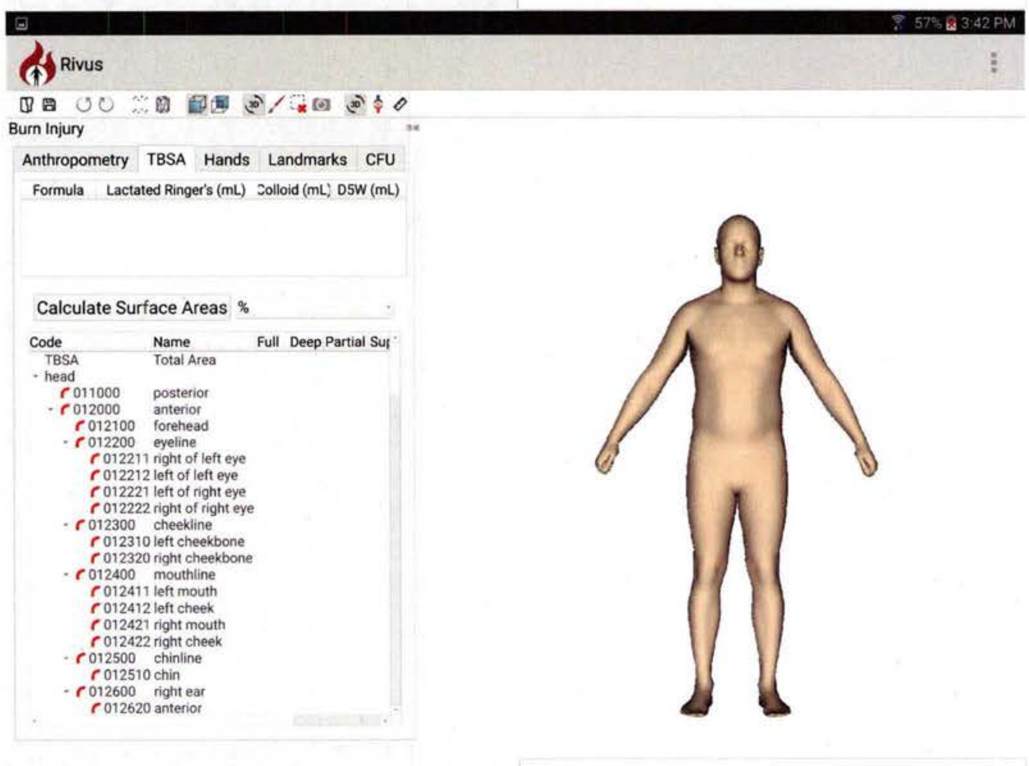
2 weight 40.0 83.7 150.0
52 waist_circum 0.638 0.957 1.276
Search
Show Advanced Features
Reset

(b)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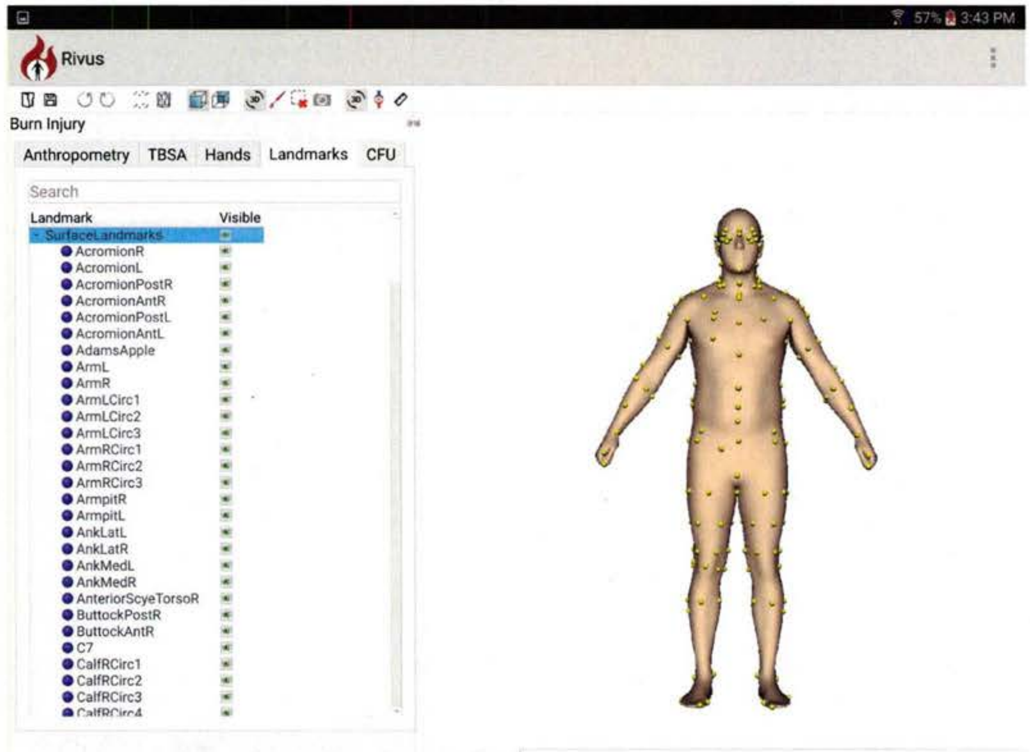
Rivus
Burn Injury
Anthropometry TBSA Hands Landmarks CFU
Formula Lactated Ringer's (mL) Colloid (mL) D5W (mL)
Calculate Surface Areas %
Code Name Full Deep Partial Sup
TBSA Total Area
head
011000 posterior
012000 anterior
012100 forehead
012200 eyeline
012211 right of left eye
012212 left of left eye
012221 left of right eye
012222 right of right eye
012300 cheekline
012310 left cheekbone
012320 right cheekbone
012400 mouthline
012411 left mouth
012412 left cheek
012421 right mouth
012422 right cheek
012500 chinline
012510 chin
012600 right ear
012620 anterior

(c)



(d)

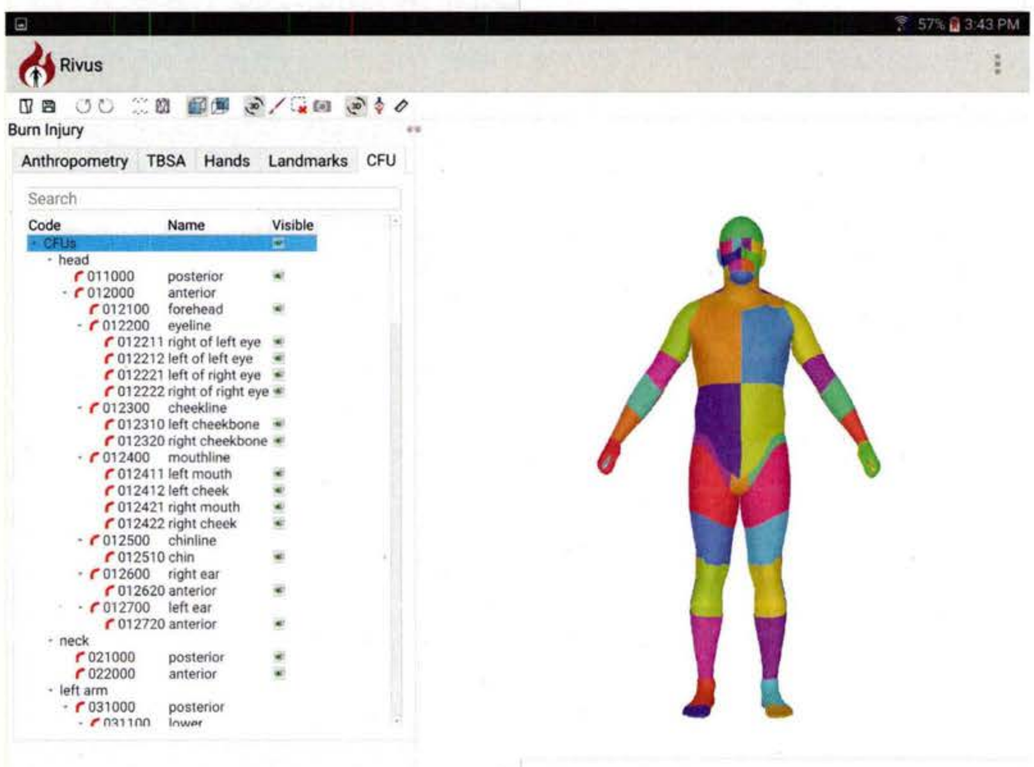
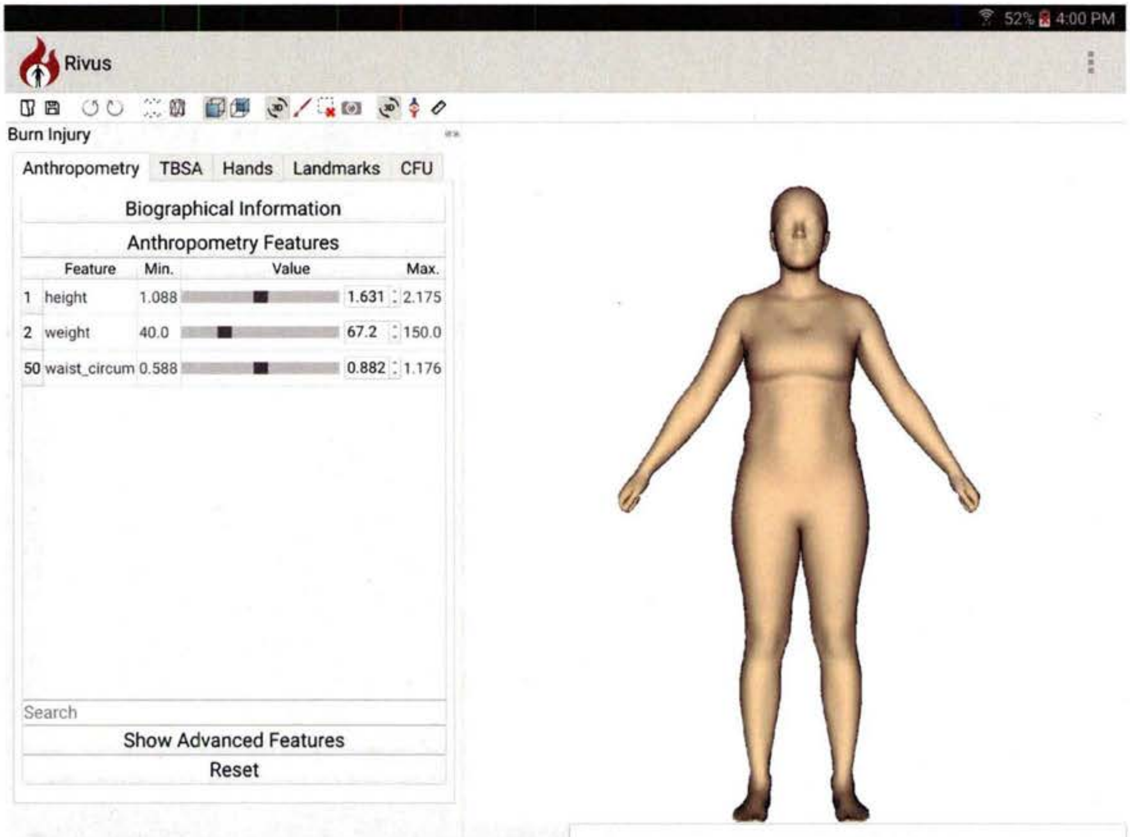
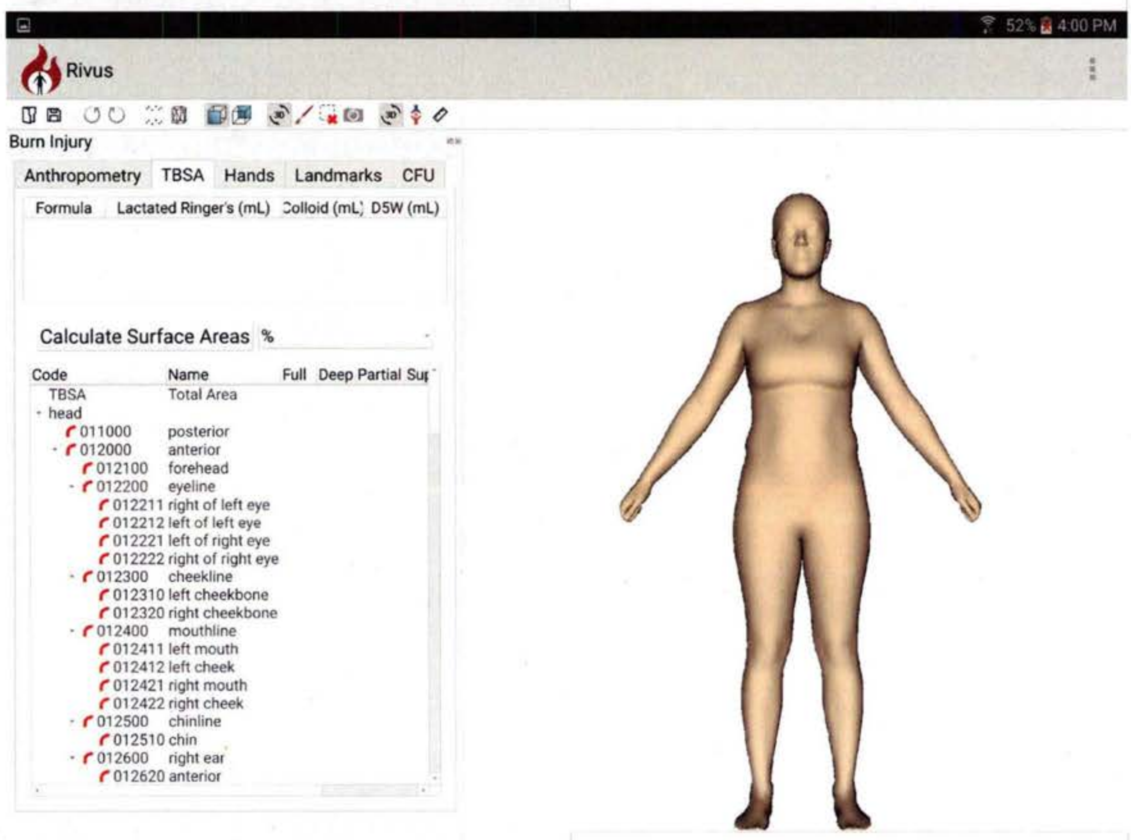


Figure 3: Initial mobile prototype running on Android 6.0 on Android tablet device with armeabi-v7a processor with the mean male model showing the (a) Anthropometry tab, (b) TBSA tab, (c) Landmarks tab with landmarks (yellow spheres) displayed, and (d) CFU tab with CFUs displayed.

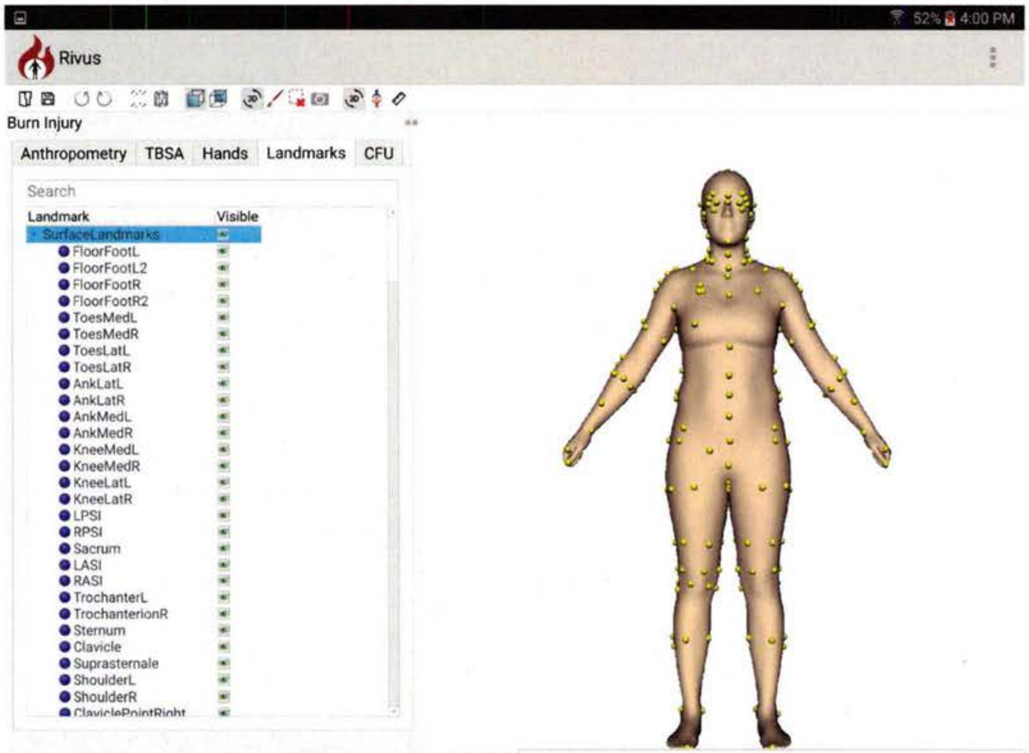
(a)


52% 4:00 PM
Rivus
Burn Injury
Anthropometry
TBSA
Hands
Landmarks
CFU
Biographical Information
Anthropometry Features
Feature Min. Value Max.
1 height 1.088 1.631 2.175
2 weight 40.0 67.2 150.0
50 waist_circum 0.588 0.882 1.176
Search
Show Advanced Features
Reset

(b)


52% 4:00 PM
Rivus
Burn Injury
Anthropometry
TBSA
Hands
Landmarks
CFU
Formula
Lactated Ringer's (mL)
Colloid (mL)
D5W (mL)
Calculate Surface Areas
%
Code Name Full Deep Partial
TBSA Total Area
head
011000 posterior
012000 anterior
012100 forehead
012200 eyeline
012211 right of left eye
012212 left of left eye
012221 left of right eye
012222 right of right eye
012300 cheekline
012310 left cheekbone
012320 right cheekbone
012400 mouthline
012411 left mouth
012412 left cheek
012421 right mouth
012422 right cheek
012500 chinline
012510 chin
012600 right ear
012620 anterior

(c)



(d)

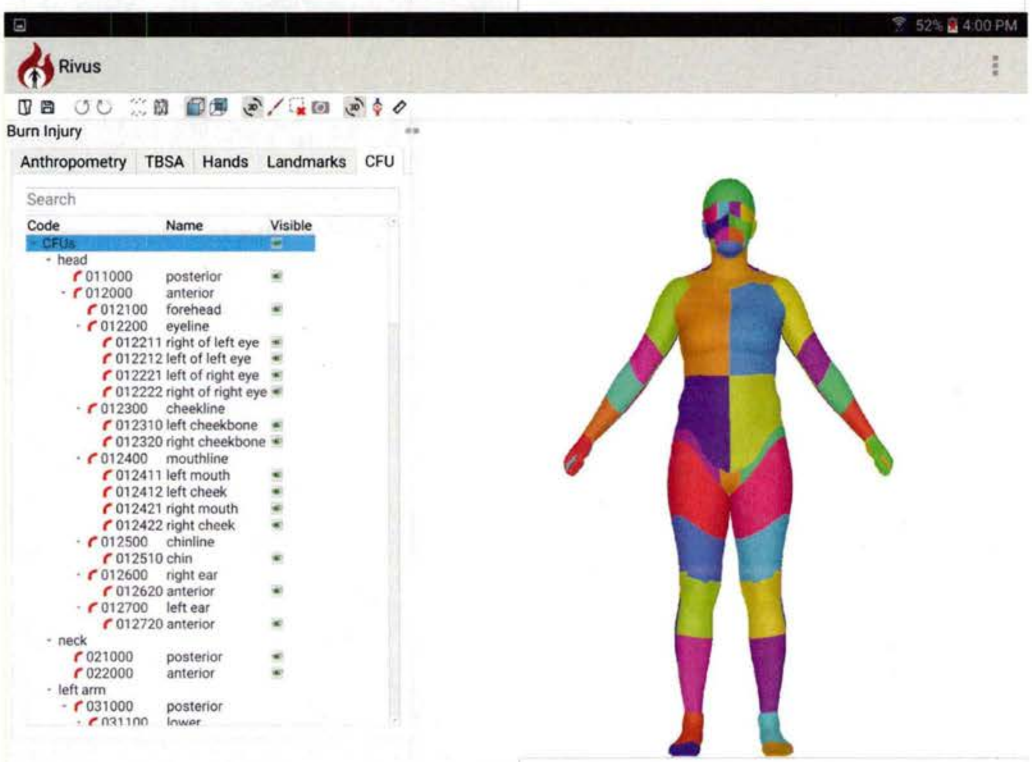


Figure 4: Initial mobile prototype running on Android 6.0 on Android tablet device with armeabi-v7a processor with the mean female model showing the (a) Anthropometry tab, (b) TBSA tab, (c) Landmarks tab with landmarks (yellow spheres) displayed, and (d) CFU tab with CFUs displayed.

The 3D male and female models can be morphed by adjusting the anthropometry feature sliders. Currently, height, weight and waist circumference are the 3 anthropometry features that can be modified, but this will be changed as the project progresses into Phase II. The sliders have been made bigger for easier contact on the touchscreen. As the project progresses into Phase II, the GUI will be reworked to be more touch friendly. Additionally, as the 3D human body deforms, the landmarks and CFU also morphs accordingly (Figure 5 and Figure 6).

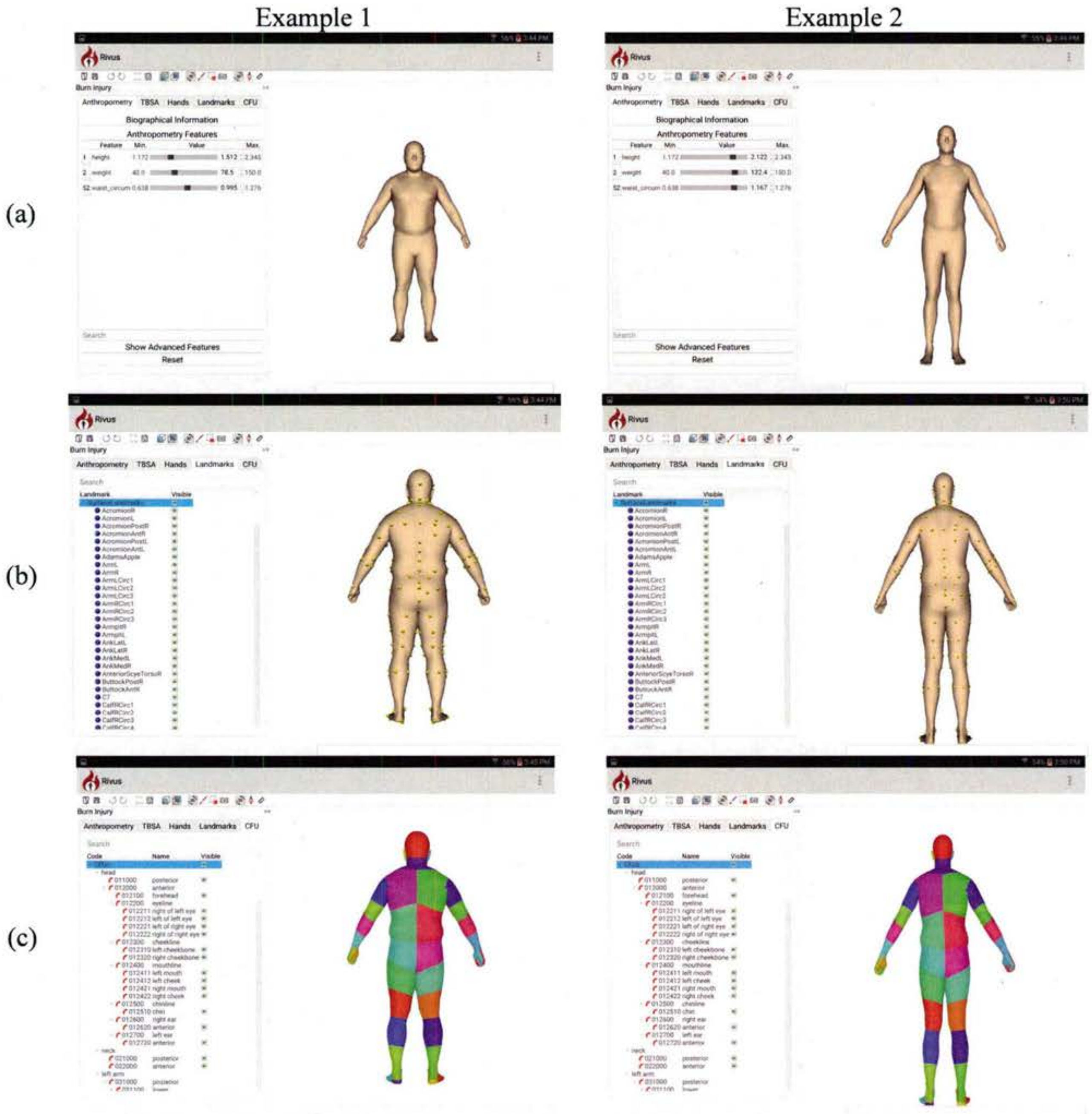


Figure 5: Examples of (a) morphing of the male model on the mobile Android prototype along with back views of deformed (b) landmarks positions (yellow spheres) and (c) CFUs.

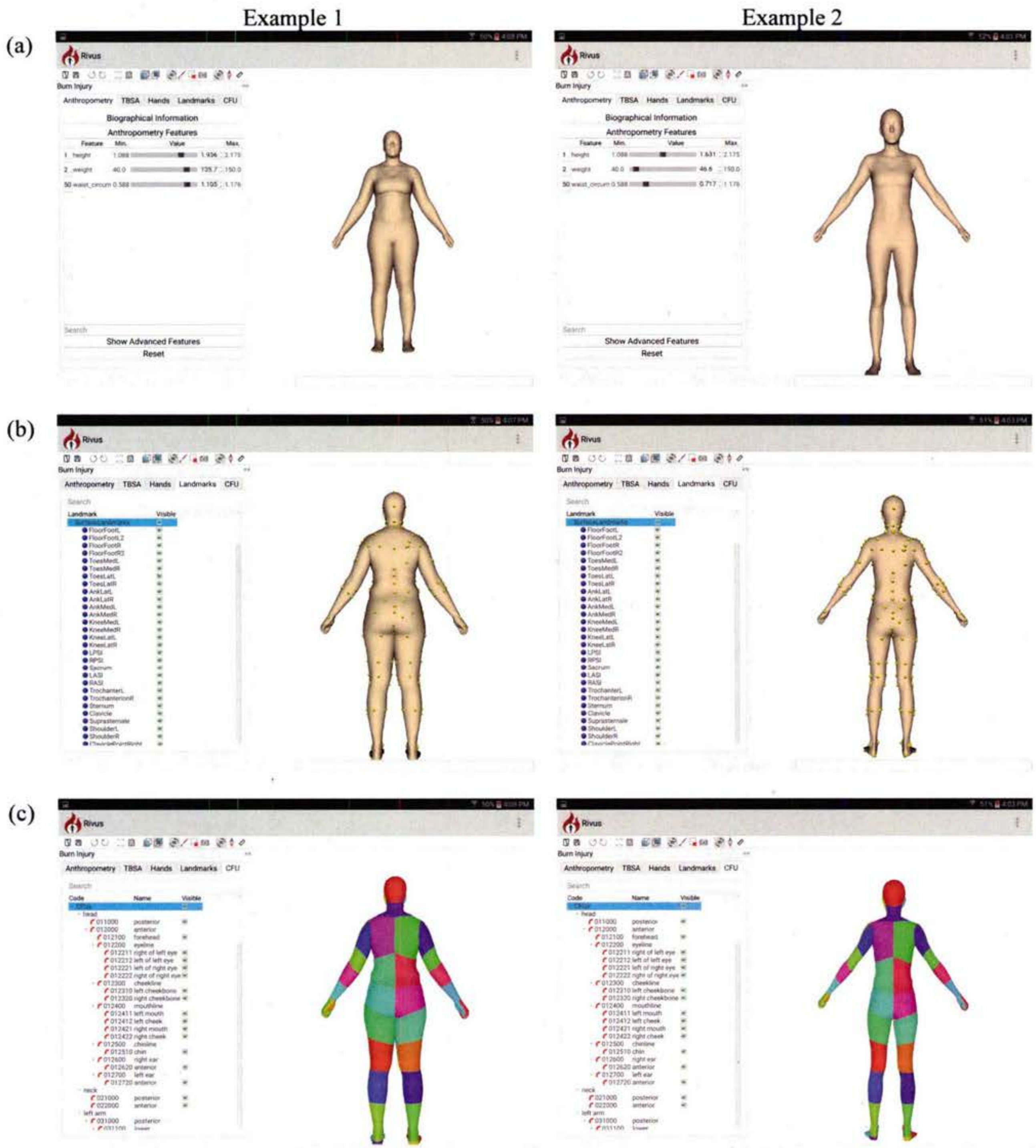


Figure 6: Examples of morphing of the female model on the mobile Android prototype along with back views of deformed (a) landmarks positions (yellow spheres) and (c) CFUs.

Issues

Despite the success in porting our existing Windows-based burn injury assessment code to Android, there are still a number of issues to resolve to restore all functionalities. All these issues will be addressed and resolved in Phase II. One of them is the burn demarcation which is unavailable now due to upgrading of the QGLWidget with QOpenGLWidget class, thereby eliminating the recognition of keyboard controls during any manipulations. Furthermore, GUI modifications will be needed to include a demarcation switch for the Android device where no keyboards are available. Another issue is the time lag in 3D human model morphing on the Android device due to its limited computational processing unit (CPU) speed. Table 1 lists the lag times during model morphing on various Android devices with difference CPUs. With the slowest Android tablet, the time lag is about 3 seconds. The time lag reduces to about 1 second with the second fastest Android tablet. With the latest generation of Android tablet and the fastest CPU, it is expected that the morphing would be in real-time with no lag. We will also explore a different algorithm for morphing that relies on searching of an extensive anthropometric database, which is created from thousands of randomly generated human models, for the closest 3D human model based on the anthropometry features. This may be a less computationally intensive approach and faster. Finally, the GUI will need to be reworked to be touch friendly and to accommodate the limited screen size.

Table 1: Time lag during 3D human body model morphing on Android devices [9].

Tablet	CPU speed [GHz]	Time lag [s]
Samsung Tab A 8"	1.2 Quad-Core	~3
Samsung Tab S2 9.7"	1.9, 1.3 Octa-Core	~1
Samsung Tab S3 9.7"	2.15, 1.6 Quad-Core	untested

2.3. Option Task 3: Project Management, Planning and Commercialization

Throughout the duration of the project, internal discussions and software reviews were carried out between members of the CFDRC team to ensure technical accuracy, satisfaction of software requirements and timely progression of project.

3. KEY RESEARCH ACCOMPLISHMENTS

In this Phase I Option project, we further developed the capabilities of the functional prototype tool created in Phase I Base to use photographic images of burned body parts for image-assisted burn demarcations as well as expanded its compatibility to the Android mobile platform.

We are pleased to report that the main goals of Phase I Option have been successfully accomplished and they include:

1. Developed the capability to use photographic images of burned body parts to assist in burn demarcations by superimposing the images onto the body. Opacity of the image can be altered by the user and demarcation onto the body can be carried out directly on the image, allowing the burn areas to be essentially traced onto the 3D body model. Expanded the software tool to load more image formats, including BMP, JPEG, PNG and TIFF, for image-assisted burn demarcations.
2. The Phase I Base functional prototype developed for Windows operating system in Visual Studio Community was ported to Qt Creator IDE where cross-platform (Android and Windows) development can be performed. The dependency on CMake to compile the software is no longer required. The code was also refactored for compatibility with Android NDK r13b.
3. The input files required for 3D human male and female body morphing are set up to be bundled within the executable during compilation, either APK or Windows EXE, to provide some degree of protection for the PCA data from ANSURII survey.
4. The burn injury assessment prototype runs on both Windows and Android device with armeabi-v7a processor. The Windows version is fully functional while the current Android version has less functionality and is still a work in progress to be continued in Phase II.

4. CONCLUSION

4.1 Project Importance and Implications

We have developed a burn injury assessment software tool that can generate in real-time, anthropometrically realistic virtual 3D human body model representation of the burn patient, which is subsequently used to demarcate burn areas based on burn severity and compute the %TBSA and fluid resuscitation recommendations. Photographic images of burned body parts can also be used to assist in burn demarcations. This tool may greatly improve the accuracy of TBSA and burn area estimations, and thereby %TBSA and ultimately treatment recommendations. Given physicians generally overestimate %TBSA with current traditional methods [5] with the most experienced burn physicians routinely overestimated %TBSA by 20%, while the less experienced ones overestimated by up to 49% [1], improvements in %TBSA and therefore proper burn treatments may ultimately result in better patient outcome and lower risk of complications.

In the U.S. alone, there are 127 specialized burn centers with another 4,500 acute care hospitals that will be just a download away from our software tool. The tool can also be used in telemedicine, whereby photographic images of burned body parts and patient's anthropometric measurements can be collected onto the tool and all that information can be securely shared with burn specialists at another location. Users can contact us on our website (www.medicalavatars.com) with regards to questions, comments, and bug reports. This will enable possible bugs and issues not detected during our internal testing to be identified and remedied.

4.2 Work Plans for Phase II

Successful proof-of-concept demonstrations in Phase I and Phase I Option strongly justify Phase II continuation. Phase II effort will focus on the expansion, improvements and refinements of the functionalities developed in the prototype in Phase I and Option as well as validation of the surface area calculations on burn patients. We plan to establish close collaboration with Prof. David Herndon from UTMB and Shriners Hospitals for Children, our consultant during Phase I and Option, to test out our software tool on actual burn patients by physicians and nurses. The planned Phase II tasks are:

Enhance and Improve Existing Prototype: The existing prototype developed in Phase I and Option will be improved upon with better user controls during burn demarcations of the model. The capability to undo and redo demarcation for each burn severity will be added to alleviate the relative time intensive and error prone burn demarcation process. For the mobile app, the GUI will be reworked for the touch friendly and limited screen size. Optimization of software and workflow will also be carried out to ensure ideal performance on the limited computing resources on the device. Lastly, touch-based burn demarcation will be developed.

Selective Refinement of Human Body Surface Meshes: The larger surface mesh triangles of the 3D human body models, mostly on the abdomen, back, and upper arms and legs, may cause overestimation of the burn area since only full triangles are selected and counted towards surface

area. Algorithms to subdivide triangles on the mesh that are larger than a user-defined tolerance will be developed to minimize these inaccuracies. Additionally, the eigenvectors for each vertex from the PCA will be interpolated for the newly added vertices using the inverse distance weighting method. Tests and statistical analyses will be performed to ensure interpolation is sufficiently accurate and if more complex interpolation methods are required.

Develop Patient Database: Patient data entered (name, gender, age, anthropometric measurements), collected (photographic images), all generated and processed data (burn surfaces, %TBSA, %CFU), and treatments (fluids and medications administered) will be organized and stored in a database management system (MS-SQL or Oracle). This type of relational file management system is highly flexible, scalable to a large number of patients and adaptable to additional file formats as well as potentially translatable to web applications for telemedicine. The database will be designed for easy navigation organized by each patient for different data types and dates. Additionally, multiusers can interact at any point of the workflow using synced data from the database. One user can stop the workflow midway, saving all entered data into the database, and another user can subsequently continue with the workflow by reloading all the data from the database. Any information stored in the database can also be selected and exported in various formats including PDF and CSV.

Anthropometric Body Generation for Children: Children anthropometric and PCA data from a recent 2015 survey of 137 subjects aged from 3 to 11 years will be improved with higher resolution models, resolving significant artifacts, and provided to us by our collaborator, Prof. Matthew Reed from UMTRI [10]. The child dataset will be reviewed and processed to be compatible for use in our anthropometry body generator to create personalized child body model based on a variety of anthropometry parameters (stature, weight, lengths of arm and leg, widths of head, shoulder, and hip, circumferences of chest, waist, and hip). Additional landmarks may be added to the template model to obtain the same anthropometry measurements for the adult models. Classification of the CFU will also be performed on the child template model.

Develop Full Body Model Articulation: Full articulation of the joints in the ANSUR II models maybe needed to reach hard to reach body parts for burn demarcation, e.g. armpits and groin regions. We have previously added a skeletal framework to the ANSUR II male model through an Army SBIR Phase II project, "Whole Body Anthropometric Design Models for Protective Equipment Design", thereby enabling full body articulation as well as scaling with morphing of the whole body and each body part independently to simulate compartment swelling after burns. This skeletal framework will be added to our male and female adult and child model as well. Controls to perform the articulation and scaling will also be added to the GUI.

Specialization for Burns to Hands: Hands are one of the top body parts to get burned and the quality of life of burn survivors is determined greatly by how much dexterity is recovered in the hands [11]. However, the hands are in closed positions in the current ANSUR II and UMTRI models, making it difficult to accurately demarcate. An articulating framework, described in previously for the whole body, will be developed specifically for the hands that include each finger and joint. This will allow the hands to be opened up for CFU classification and mesh refinements if necessary. A dedicated GUI window will be developed to focus on burns to the hands where hand breadth and length can be adjusted in real-time.

Develop Image Acquisition Guidance for Alignment: For the mobile version of our software tool, we will take advantage of the built-in camera in these devices to acquire photographic images of burn areas. We will develop a photo acquisition guide in the tool to direct the user to take images of the patient at the correct zoom and angle for direct alignment with the 3D model without the need for any post-processing registration. The exact outline of the virtual personalized anthropometric body model can be determined, and each specific burned body regions can be isolated by the user and displayed on the screen in camera mode to guide the user.

Anthropometric Body Generation for Toddlers: Our collaborator from UMTRI will analyze standing scan data from approximately 60 toddlers, ages 12 to 36 months, measured in a recent UMTRI study. The surface model resolution will be improved and any significant artifacts resolved. The resulting enhanced model will be integrated with the older child model previously developed to enable modeling from 1 to 11 years (for pre-pubescent children only). Our child model will be updated with this data from this child dataset. Since model surface triangulations will remain the same, the CFU classifications and body and hand articulations developed previously will also stay unchanged.

Thermal Image-Based Burn Depth Estimation: Infrared thermal imaging can be used to measure differences in temperature between burned and healthy skin, which can then related to burn depth [12]. The thermal images acquired will be uploaded into our software tool to compute the differences in temperature between healthy and burned tissue, which will aid in distinguishing between superficial and deep burns. The processed thermal image can then be manually aligned to the 3D personalized human body model and superpositioned for image-assist demarcation.

Software Validation on Burn Patients: Validation of the %TBSA and %CFU calculated will be performed on prospective burn patients with the assistance of our collaborator, Prof. Herndon, who has access to burn centers, UTMB and Shriners Hospitals for Children in Galveston. In addition to Prof. Herndon, physicians and nurses from both hospitals have all agreed to participate in using our software tool for validation and offer feedback. These feedbacks will be implemented and software updates will be issued. We will work with the university, hospital and Prof. Herndon as well as internally at CFDRC for the proper approvals (IRB) midway into Year 1 as well as obtain patient consent to conduct this study. Differences between %TBSA measured using our software tool and Lund-Browder will be analyzed.

Software Environment and Platform Compliance: Our software tool will be further developed to comply with the requirement that it functions on virtual machines (VMware) in the Development/Validation Environment (DVE) of the U.S. Army, which uses Windows 2008R2 server, MS-SQL and Oracle database, and Windows 7 operating systems. We will work with the Army to transfer our software onto their specific U.S. Army MEDCOM environment and accommodate any changes required. Feedback obtained from the Army end users will be used to improve existing capabilities and add desired features.

5. PUBLICATIONS, ABSTRACTS, AND PRESENTATIONS

Nothing to report.

6. INVENTIONS, PATENTS AND LICENSES

Nothing to report.

7. REPORTABLE OUTCOMES

In this Phase I Option project, we have further developed the capabilities of the functional prototype tool, created in Phase I Base, to use photographic images of burned body parts for image-assisted burn demarcations and expanded its compatibility to the Android mobile platform. The Android app can generate anthropometrically realistic virtual 3D human body model representation of the burn patient (Figure 7).

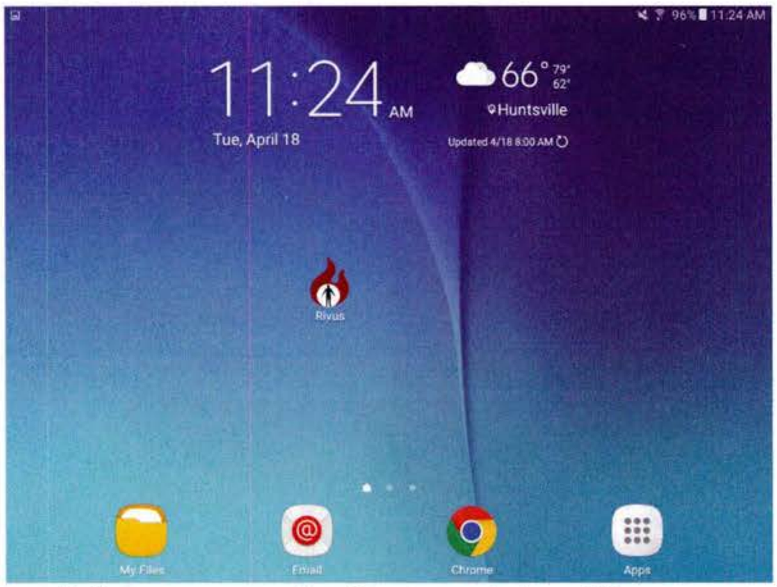


Figure 7. Our burn injury assessment software prototype, Rivus, on an Android device.

8. OTHER ACHIEVEMENTS

Nothing to report.

9. REFERENCES

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10. APPENDICES

QUAD CHART

Burn Injury Assessment Tool with Morphable 3D Human Body Models

CFDRC Delivering Breakthrough Solutions

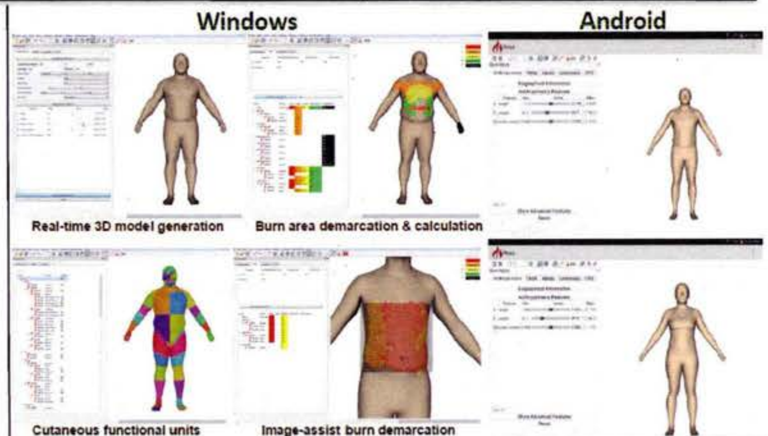
PI: **Kay Sun** | Organization: **CFD Research Corporation** | **SBIR A151-055 Phase I Option** | Award Amount: **$49,981.50**

Study Goal

Develop a burn injury assessment tool with morphable 3D anthropometric human body models to improve the accuracy of percentage burn surface area (%TBSA) estimates.

Approach

Develop a burn injury assessment tool that can
- Generate in real-time virtual 3D anthropometric male/female body model.
- Interactive demarcation of burn areas with different severity and amputation.
- Calculate and report burns based on TBSA and cutaneous functional units (CFU) as well as fluid recommendations.
- Use photographic images of burned body parts to assist in burn demarcations.
- Run on Windows and Android platforms.



Accomplishment: **Developed a burn injury assessment tool for Windows and Android.**

Timeline and Cost

Activities	2015	2016	2017	2018
Prototype on Windows 7 (Phase I)				
Prototype on Android (Phase I Option)				
Patient Database (Phase II)				
Body Articulation (Phase II)				
Burns to Hands (Phase II)				
Burn Depth Estimation (Phase II)				
Patient Validation at UTMB (Phase II)				
Software Delivery (Phase II)				X
Estimated Budget ($)	100k		50K+500K	500K

Updated: April 21 2017

Goals/Milestones

Phase I (2015 – 2016) – Prototype on Windows

☑ Completed development of functional prototype on Windows.

Phase I Option (2017) – Prototype on Android

☑ Testing of prototype on Android mobile platform.

Phase II (2017) – Expand capabilities

☐ Patient database with printable outputs.

☐ Full body and finger articulations.

☐ Burns to hands.

Phase II (2018) – Expand capabilities and validation

☐ Capture & integration of infrared images for burn demarcations.

☐ Validation on burn patients at U. of Texas Medical Branch & Shriners Hospital for Children (Prof. David Herndon).

Budget Expenditure to Date

Projected: $49,981.50 Actual : $49,981.50